State of Utah

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DIVISION OF WASTE MANAGEMENT
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Director

MEMORANDUM

TO: File

THROUGH: Phil Goble, Manager PRG 3/14/18

FROM: Tom Rushing, P.G. JR 3-14-18

DATE: March 14, 2018

SUBJECT: Review of the Energy Fuels Resources (USA) Inc. (EFR), White Mesa Uranium Mill, Blanding, Utah August 21, 2017 Source Assessment Report for Selenium, Sulfate, Total Dissolved Solids (TDS) and Uranium in Monitoring Well MW-31, Ground Water Discharge Permit UGW370004

Summary

An August 21, 2017 Source Assessment Report ('SAR") for Selenium, Sulfate, TDS and Uranium in Monitoring Well MW-31 at the White Mesa Uranium Mill (Mill) was submitted to the Director by Energy Fuels Resources (USA) Inc. ("EFR"), and received on August 23, 2017 for review and approval of proposed revised Ground Water Compliance Limits (GWCLs).

Monitoring well MW-31 is located on the southeast berm of the Mill tailings cell 2 and is hydraulically downgradient from eastern portions of cell 2 and from the Mill processing areas. MW-31 is within the defined nitrate/chloride plume, and non-compliance for nitrate and chloride are regulated through a separate consent order (UGW12-04) issued by the Director.

The SAR is broken up into four primary sections, 1. The approach for analysis of potential sources of the contamination, 2. Results of the analysis (e.g. changes in groundwater in MW-31, indicator parameter analysis, pH analysis, sorption analysis and mass balance analysis), 3. Statistical evaluation and calculation of revised GWCL's for trending parameters, and, 4. Conclusions and recommendations.

The SAR notes that though uranium is the only parameter required for assessment (in out-of-compliance status) by Part I.G.2 of the White Mesa Mill Groundwater Discharge Permit (Permit), the EFR SAR is additionally addressing exceedances of the recalculated GWCL's, noting that increasing trends are also observed for these parameters (Se, SO4, TDS).

Figures below depict the rising concentration trends in monitoring well MW-31 for Se, SO4, TDS and U using all available historical data. An additional Figure depicts the pH plot for all historical data available for monitoring well MW-31 which shows a slight decreasing trend.

Figure - Selenium Data Plot of Historical Data at MW-31 – Increasing Trend

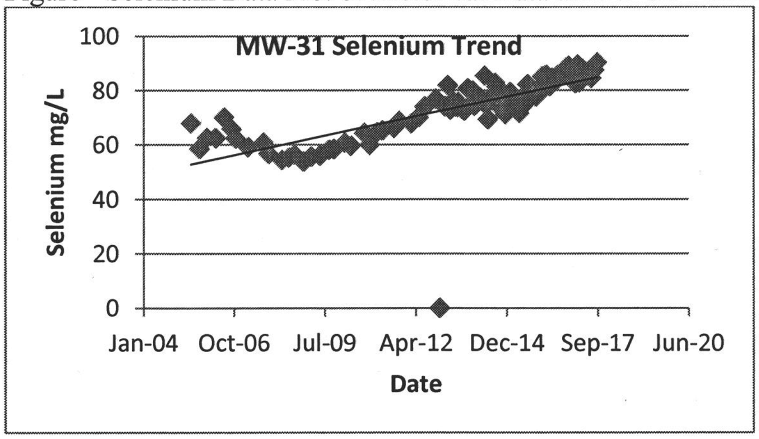


Figure – Sulfate Data Plot of Historical Data at MW-31 – Increasing Trend

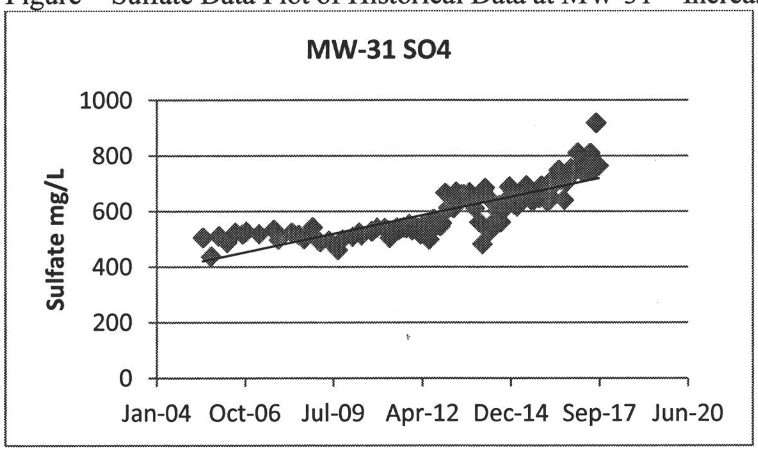


Figure – TDS Data Plot of Historical Data at MW-31 – Increasing Trend

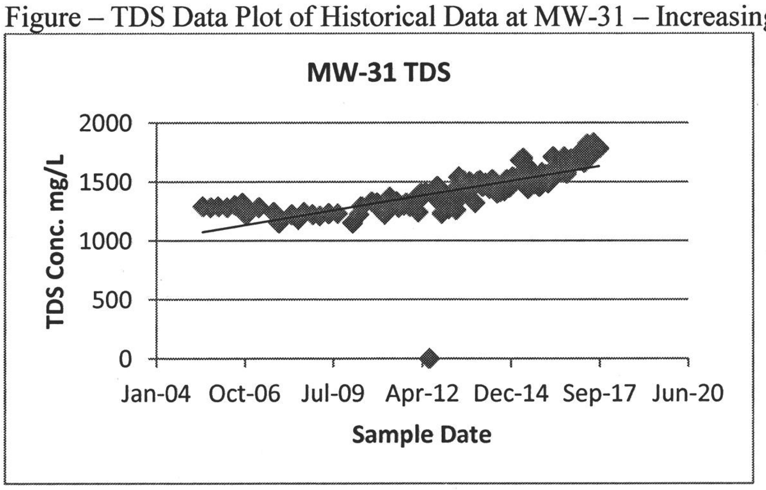


Figure – U Data Plot of Historical Data at MW-31 – Slight Increasing Trend

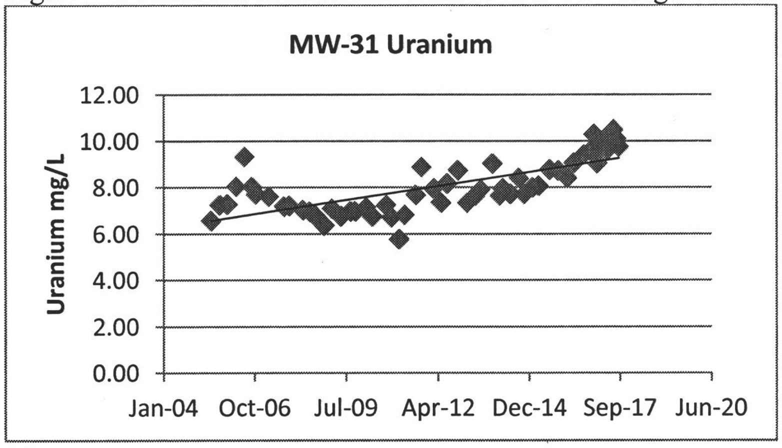
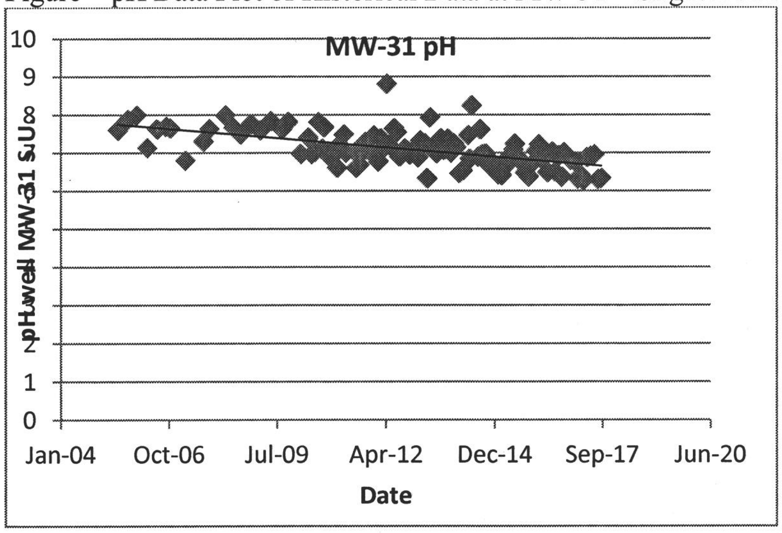


Figure – pH Data Plot of Historical Data at MW-31—Slight Decreasing Trend



Based on the increasing trends, EFR is proposing that the use of higher GWCL's allowed by the Utah Administrative Code R-317-6 should be considered and are in conformance with the Director approved statistical flow chart for GWCL's. Conclusions of the SAR find that the GWCL exceedances and increasing trends are not caused by releases from the Mill as discussed below.

<u>EFR Investigations of Potential Sources of Report Increasing Trends at Monitoring Well MW-31</u>

1. Changes in Mill Groundwater Operations

Section 3.1 and time series plots included as Appendix C-10 of the SAR discuss several Mill operational and environmental changes that appear to be consistent with data inflections seen on the time series plots. Specifically these changes are; 1. The initiation of monthly groundwater sampling in 2010; 2. A well redevelopment project in 2011; 3. A change in environmental laboratory used in 2012; 4. A peak groundwater elevation at MW-31 in 2013; and, 5. Five new chloroform wells brought online on the east side of Cell 2 in 2014. Per DWMRC review of the time series plot it is observable that the trends in MW-31 and at other sitewide monitoring wells appear to begin in late 2010 and 2011, during the time of initiation of increased frequency (monthly monitoring) and the well redevelopment project, which included overpumping all monitoring wells at the Mill. These actions may have introduced/allowed oxygen to enter pores within the sandstone and shales of formations in the well screened intervals and caused geochemical reactions within the minerals of those zones. Also, an inflection in certain monitoring analytes and wider scattering of data is clearly seen in 2012 when the analytical laboratory was changed.

Per DWMRC findings regarding time series plots of data, the data inflection seen late 2012, for certain parameters indicates a shift in background concentrations due to the laboratory change. For parameters where this is observed in MW-31, and consistent with the EPA 2009 Unified Statistical Guidance, it is appropriate to use the data after this inflection to evaluate the background data.

2. *Discussion of Tailings Solution Groundwater Indicator Parameters at Monitoring Well MW-31*

The SAR Section 3.2 discusses four primary indicator parameters (Chloride, Fluoride, Sulfate and Uranium) which would be detected in ground water in the event of discharge from the Mill tailings cells. Mass balance evaluation comparisons at MW-31 included Fluoride and Sodium, as representative mobile contaminants for comparison with the study parameters (CL, Sulfate and Uranium).

Piper diagrams evaluating chemical relationships of Cell 1 wastewater and observed groundwater concentrations are included in the SAR. Additionally, the SAR includes an evaluation of upgradient well data and downgradient well data in comparison with current data from MW-31. Based on this review, fluoride, sulfate and uranium concentrations in MW-31 are within the same background range of monitoring wells upgradient and far downgradient from the Mill. The evaluation confirms that chloride concentrations in MW-31 are well above background range, as expected, based on the MW-31 location within the nitrate/chloride plume.

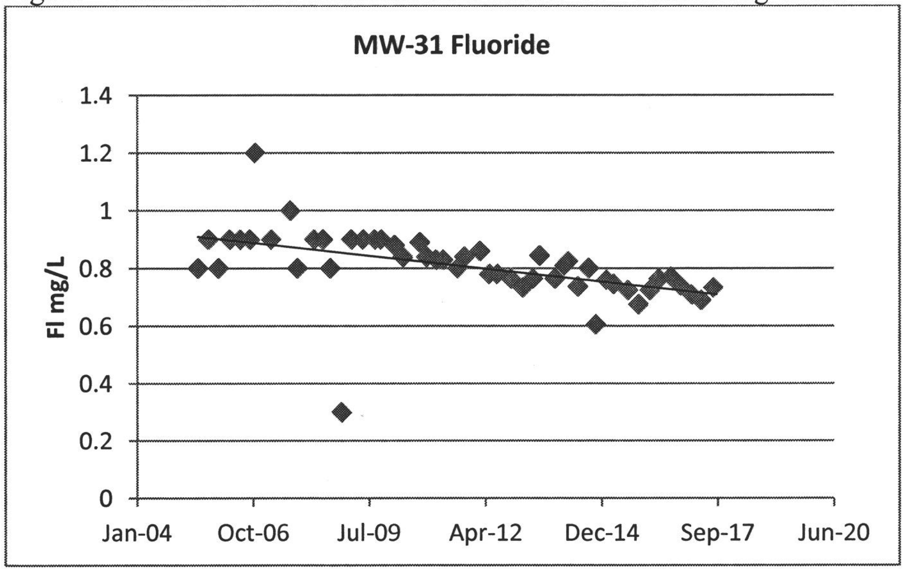
<u>*Chloride*</u>

Per the SAR, the use of chloride as an indicator parameter in the case of monitoring well MW-31is complicated by the fact that MW-31 is screened within a nitrate/chloride plume, and chloride is therefore above background and is not a reliable primary indicator of cell leakage for MW-31. Chloride at monitoring well MW-31 is showing a significant increasing trend. Findings related to comparisons of MW-31 chloride and background wells outside of the nitrate/chloride plume show chloride well outside of background range. The chloride plume has been delineated based on concentrations and plots clearly show that the plume leading edge is hydraulically upgradient from the mill tailings cells and is not attributed to tailings cell leakage based on groundwater flow data and mass balance calculations.

<u>*Fluoride*</u>

Fluoride is highly concentrated in tailings wastewater and per literature and mill groundwater transport modeling has been shown to be highly mobile in the vadose zone and groundwater beneath the tailings cells. Per the figure below, fluoride is showing a decreasing concentration trend in MW-31.

Figure – Fluoride Plot of Historical Data at MW-31 – Decreasing Trend



Mass balance calculations for fluoride are included in the SAR. Per presented findings the concentration of fluoride in groundwater when compared with less mobile constituents in tailings wastewater are much lower that less mobile constituents and additionally as per the figure above are declining. The SAR uses a comparison of selenium and fluoride in Cell 1 tailings wastewater and MW-31 groundwater and notes that selenium is found at much higher percentages in groundwater than fluoride. Fluoride concentrations should be over 20 times higher to indicate a relationship with tailings wastewater.

Sulfate

Sulfate concentrations in MW-31 are very low in comparison with other wells at the site. The highest historic value of sulfate is 916 mg/L (2nd Quarter 2017). This concentration is compared with highest historical values of other site monitoring wells (nearby MW-31) on the table below:

Monitoring Well No.	Location Relative to Tailings Cells	Highest Historic Measured Sulfate Value (mg/L)	Average Sulfate Concentration (Complete Data Set) (mg/L)
MW-31	Downgradient Cell 2	916	605
MW-1	Upgradient	1,990	837
MW-18	Upgradient	2,020	1,828
MW-19	Upgradient	1,320	669
MW-20	Far Downgradient	4,090	3,526
MW-03A	Far Downgradient	5,940	3,568
MW-29	Downgradient Cells 1 and 2	2,980	2704
MW-11	Downgradient Cells 2 and 3	1,360	1,105

The SAR additionally includes box plots comparing groundwater chemistry and concentration in all wells with MW-31. Per DWMRC review, the sulfate concentrations in MW-31 are low by comparison site wide. Sulfate concentrations are rising at several of the monitoring wells at the mill including upgradient and far downgradient monitoring wells. EFR notes that the increasing sulfate in many wells and corresponds to decreases in pH. Additionally, EFR offers this as a possible explanation for increases in some metals in solution at those corresponding wells, including uranium.

In the case of MW-31, the relatively low concentration of sulfate indicates a source other than tailings solution. Additionally, a clear data shift is observed to have started in 2012 in association with the change of laboratory.

Uranium

Uranium concentrations in monitoring well MW-31 are similar to sulfate concentrations in that site-wide they are low, as demonstrated by box plot evaluation comparing uranium concentration in MW-31 to all monitoring wells site wide. Box plot evaluation finds that the uranium concentrations in MW-31 are within background concentration range and are low for the mill site. The SAR discusses that rising uranium concentrations are likely associated with lower pH in the groundwater.

Indicator parameters, other than chloride, are seen to have low site wide concentrations regardless of trends. Per SAR evaluations of ratios of the mobile contaminants in groundwater with the tailings wastewater concentrations, it appears that the source of the mobile contaminants is due to causes other than tailings wastewater.

3. pH Analysis

Section 3.3 and Appendix D of the SAR include an evaluation of pH in MW-31. The analysis includes statistical evaluation (identification of outliers and trend analysis) which confirmed a significantly decreasing trend in pH in MW-31. EFR then conducted a site wide analysis for selenium trends (included as Appendix F of the SAR) and noted that 13 mill monitoring wells appear to have significantly increasing selenium trends. Of the 13 monitoring wells with increasing selenium trends, 10 have significantly decreasing pH trends. The SAR argues that the site wide distribution of pH declines and selenium increases links the reaction as related but not associated with mill activities or tailings wastewater.

DWMRC review of upgradient wells (MW-1, MW-18 and MW-19) does confirm decreasing pH trends in all three monitoring wells, however, an increasing selenium trend is only observed in monitoring well MW-19 and is probably due to the formation of a groundwater mound from infiltration from the wildlife ponds.

Per review, it is agreed that in general, decreasing pH trends appear in select monitoring wells site wide, including far upgradient and far downgradient wells. The rising selenium and uranium concentrations in MW-31 may be related to decreases in pH. However, based on review of the SAR, there does not appear to be a consistent site-wide correlation sufficient to generalize the sorption reactions for a group of monitoring wells. The Dakota/Burro canyon aquifer material is heterogeneous, as evidenced by drill logs and area geological investigation. Geochemical reactions will be dependent on minerology of discreet geological zones; this is recognized and is the basis of intrawell background and statistics at the White Mesa Mill.

4. Sorption Analysis

Section 3.4 of the SAR provides a simple model, using Geochemist's Workbench (v. 11), of potential mineral sorption for MW-31. The SAR notes that iron oxides have been identified in most of the boring logs at White Mesa, and that per confirmation through X-Ray diffraction analysis of drill cuttings, "*more iron is available than can be accounted for by common crystalline iron phases such as goethite*."

The SAR questions some assumptions made in past geochemical modeling. Based on field readings of redox at MW-31, the groundwater is oxidized and pH has historically been in a neutral range. Based on these conditions it has been assumed that uranium and selenium are complexed with carbonate or oxygen and that uranium and selenium concentrations should decrease with decreasing pH.

However, the SAR states "*these early models, however, suffered from convergence issues such as charge inbalance*." The SAR discusses that calcite is present in the bedrock at 1% to 14% by weight and that the addition of calcium in modeling would allow for charge balance by calcium ions. The SAR geochemical model included calcium as an input.

Uranium and selenium sorption curves (SAR Figure 3) generated by the Geochemist's Workbench model (Appendix I), indicates decreasing uranium and selenium sorption with decreasing pH, supporting the EFR view that increasing concentrations of Se and U in solution are associated with the decreasing pH in MW-31. Per summary of the SAR findings, the decreased sorption of selenium and uranium is due to other prevalent anions (HCO_3^- and SO_4^{2-}) occupying sorption sites blocking sorption of selenium and uranium.

The SAR discusses that several assumptions were made when using input values into the model and that the Geochemist's Workbench is a simplistic model.

Per review, the modeling demonstrates that calcite has a potential effect of inhibiting selenium and uranium sorption. However, additional analysis would need to be conducted to confirm that this is the case at specific locations including batch testing to determine the impact of specific variables for more representative geochemical modeling (e.g. pH, time, presence and absence of oxygen, presence of additional minerals, etc.).

5. *Mass Balance*

The SAR includes a mass balance evaluation of current concentrations (5/2017) of fluoride, uranium, chloride, sulfate, selenium and sodium in MW-31, and average concentrations of the same parameters in cell 1 wastewater (based on averages of data collected between 2003 and 2016). The SAR clarifies that the mass balance calculations evaluate the data only for comparisons due to dilution and do not consider relative mobility of contaminants.

Based on large inconsistencies between the tailings wastewater concentrations and the expected diluted concentrations, the SAR concludes that "*modeled parameter concentrations in MW-31 differ greatly from observed concentrations of fluoride in MW-31*." Per review, the analysis indicates that the groundwater concentrations of these parameters in MW-31 are not consistent with a tailings source.

DWMRC review conducted an additional dilution based evaluation using slimes drain concentrations of Cell 2. DWMRC calculations regarding the same method to calculate mean Cell 2 concentrations (data from the Cell 2 slimes drain) from 2007 to 2016 are included on the table below:

	Units	Fluoride	Uranium	Chloride	Sulfate	Selenium	Sodium
MW-31 Concentration 5/2017	µg/L	690	9.62	2.65E+05	7.41E+05	85.2	1.05E+05
Cell 2 Concentration Slimes Drain Average (2007-2016)	µg/L	74,000	27,773	3.5E+06	6.7E+07	699	4.38+06
Dilution Factor	µg/L	0.00932432	.0003463795	.0757142857	.0110597015	.121888412	.0239726027
Predicted Diluted Fluoride	µg/L		256	5,603	818	9,020	3.08E+06

It was noted that a similar result of the SAR analysis using Cell 1 was obtained. Chloride, sulfate and selenium were underestimated and uranium was overestimated. Per evaluation it was noted that sulfate concentrations are in line with fluoride based on Cell 2 slimes drain concentrations and concentrations seen in MW-31, however, the fact that fluoride concentrations are decreasing while sulfate is increasing negates this relationship as due to a tailings source. If tailings wastewater were the source, uranium concentrations would be expected to be considerably higher and selenium concentrations considerably higher.

The table below summarizes the evaluation and includes lines indicating current May 2017 concentrations of fluoride, uranium, chloride, sulfate and selenium, and expected concentrations of uranium, chloride, sulfate, and selenium compared to fluoride if there was a release using the fluoride dilution factor for each parameter:

	Units	Fluoride	Uranium	Chloride	Sulfate	Selenium	Sodium
MW-31 May 2017 Concentrations	µg/L	690	9.62	2.65E+05	7.41E+05	85.2	1.05E+05
Mass balance concentrations expected in the event of a release from Cell 1	µg/L	690	191	9.65E+3	6.66E+04	3.2	42.9
Mass balance concentrations expected in the event of a release from the Cell 2 Slimes Drain	µg/L	690	258	3.2E+4	6.24E+05	6.5	979

The mass balance (dilution) evaluation results indicate that the source of the increasing trends is not the result of tailings wastewater release.

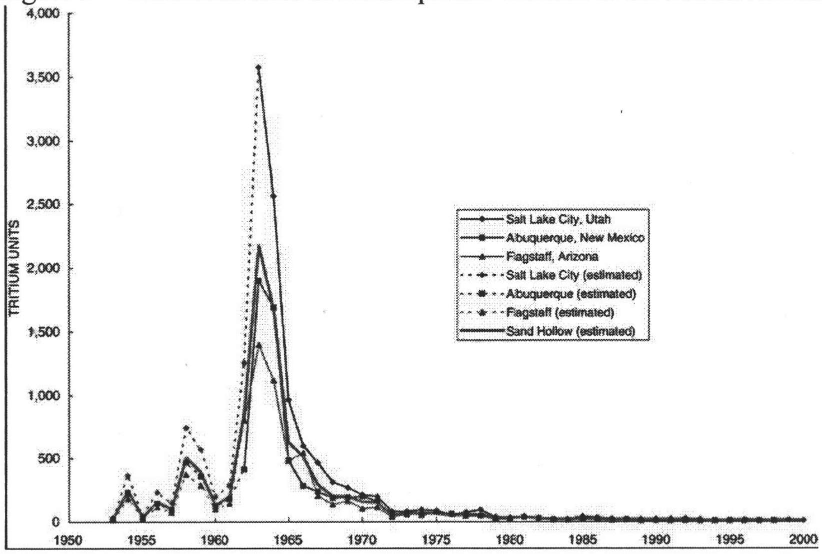
6. *University of Utah Study*

Monitoring well MW-31 was included in a University of Utah study conducted at the White Mesa Uranium Mill during 2007 (Final Report of Study Findings Dated May, 2008). Based on groundwater age dating at monitoring well MW-31 [chlorofluorocarbon ("CFC") analysis], the groundwater was found to exhibit CFC recharge dates which predate the construction of the Mill in 1980.

Additionally, tritium concentrations in monitoring well MW-31 were found to be non-detect. If ground water in monitoring well MW-31 had a surface infiltration source post 1950's (time period of atmospheric injection of tritium during above-ground thermonuclear weapons testing) then tritium concentrations would be expected in ground water samples in monitoring well MW-31. Figure 5 below is taken from the

University of Utah ("U of U") Report (Hurst and Solomon 2008) and depicts atmospheric concentrations of tritium in the southwest by year.

Figure 5 – Concentrations of Atmospheric Tritium in the Southwestern United States



Based on review of the U of U Report and specific data results for monitoring well MW-31 age dating of groundwater at the well indicates that the MW-31 groundwater predates Mill construction.

7. *Source Assessment Conclusions*

Section 3.6 of the SAR discusses the summary of results for evaluation of each of the SAR parameters at MW-31 (Se, SO4, TDS and U).

Based on EFR evaluations and studies performed and discussed in the SAR, and DWMRC review as discussed above, it appears that the Out of Compliance status (U) and rising trends (Se, SO4, TDS and U) are not due to wastewater release from the mill.

<u>EFR Proposed Modified GWCL Statistical Evaluation of Data:</u>

Based on DWMRC review of the SAR statistical analysis it was noted that analysis was conducted for the complete historic data set for MW-31 and for a post October 2012 data set. The complete data set showed normal or log normal distribution for uranium but not for selenium, sulfate or TDS. The modified data set did show normality for selenium, sulfate, TDS and uranium. Statistical methods used included; 1. Descriptive statistics for the complete and modified data sets; 2. Mean and Standard Deviation Calculation; 3. Shapiro-Wilk Test for normality; and, 4. Mann-Kendall Trend Analysis (non-normally distributed data sets). Proposed GWCL's were calculated based on Mean + 2 Standard Deviation, Highest Historical Value, Fraction of Groundwater Standard, and Background Mean Concentration times 1.5. The calculations and findings are summarized on a table in the SAR (Appendix B-1 of the SAR).

Per the DWMRC approved statistical flow chart for the White Mesa Mill groundwater monitoring wells, it was noted that if an upward trend is apparent for an analyte then a modified approach should be considered. The modified approach should allow for a GWCL which considers the increasing concentrations. Based on this, EFR calculated GWCL's according to the Utah Groundwater Rules (Utah

Administrative Code R317-6) which allow maximums to be set according to Mean + 2 Standard Deviations, 0.5 times the GWQS (Class III Water), or 1.5 times the background concentration. DWMRC findings note that setting the GWCL at a maximum value for these parameters is reasonable, given that the wells will likely exceed a more conservative GWCL in a short period of time when considering the increasing trends. This is particularly the case for selenium and sulfate in MW-31which have relatively stronger trends are present at higher concentrations.

Selenium and sulfate additionally show a defined change in background data pre October 2012. Per the EPA 2009 Unified Statistical Guidance Section 5.3, and based on verification that the increases are due to background influences, it is appropriate to use the data collected after the point of inflection and therefore, GWCL's for selenium and sulfate will use the post 2012 data set. It should be noted that the difference between the post 2012 data set mean and the complete data set mean are not significantly different. The TDS time series plot does not show a clear point of inflection and the complete data set will be used. Since uranium GWCL is being reset based on the fraction of the GWQS, the specific data sets are not used except for comparisons.

Therefore, when comparing the various calculated GWCL's it is found appropriate to set GWCL's for selenium and sulfate and TDS according to 1.5 times background for post 2012 data sets (Se and SO4) or the complete data set (TDS). Uranium will be set according to 0.5 times the GWQS. These values are in conformance with the approved statistical flow chart, the Utah Groundwater Rules, EPA Statistical Guidance and consider the increasing data trends.

A cross review of EFR calculated mean concentrations for parameters using 1.5 X background was conducted as shown on the table below. Per evaluation, the EFR mean calculations are correct and are representative of the data set used for evaluation.

Table – Comparison of EFR Background Data Set Mean Values in SAR with DWMRC Calculated Mean for Se, SO4 and TDS in MW-31

Parameter	EFR Calculated Mean	DWMRC Calculated Mean
MW-31 Selenium (Post Oct. 2012)	79.6 µg/L	80.0 µg/L
MW-31 Sulfate (Post Oct. 2012)	662 mg/L	665.1 mg/L
MW-31 TDS (Complete Data Set)	1421 mg/L	1434 mg/L

The table below summarizes the EFR calculations and background rationale for the proposed modified GWCL's.

Table of EFR Proposed Revised GWCL for Selenium at Monitoring Well MW-31:

Well Number	Parameter	Current GWCL	EFR Proposed GWCL Revision	Method to Determine GWCL	DWMRC Finding – Is Proposed GWCL in Conformance with the Statistical Flow Chart?	DWMRC Recommended Modified GWCL Based on SAR Review
MW-31	Selenium	86.81 µg/L	119.4 µg/L	1.5 X Background of Post Oct. 2012 Data Set	Increasing Trend allows for modified approach on Flow Chart. Per UAC 317-6, Class III water is allowed to be calculated by 1.5 X Background. Per DWMRC Review of the Selenium Data the modified approach appears appropriate since an increasing trend is apparent. Use of the post Oct. 2012 data set is appropriate and in conformance with EPA guidance since a data shift is noted corresponding to laboratory change.	119.4 µg/L
MW-31	Sulfate	697.6 mg/L	993 mg/L	1.5 X Background of Post Oct. 2012 Data Set	Increasing Trend allows for modified approach on Flow Chart. Per UAC 317-6, Class III water is allowed to be calculated by 1.5 X Background. Per DWMRC Review of the Sulfate Data the modified approach appears appropriate. Use of the post Oct. 2012 data set is appropriate and in conformance with EPA guidance since a data shift is noted corresponding to laboratory change.	993 mg/L
MW-31	TDS	1700 mg/L	2228 mg/L	1.5 X Background of Complete Data Set	Increasing Trend allows for modified approach on Flow Chart. Per UAC 317-6, Class III water is allowed to be calculated by 1.5 X Background. Per DWMRC Review of the TDS Data the modified approach appears	2132 mg/L

Well Number	Parameter	Current GWCL	EFR Proposed GWCL Revision	Method to Determine GWCL	DWMRC Finding – Is Proposed GWCL in Conformance with the Statistical Flow Chart?	DWMRC Recommended Modified GWCL Based on SAR Review
					appropriate; however, there does not appear to be a well-defined data shift in Oct. 2012. Recalculated GWCL uses background of complete data set.	
MW-31	Uranium	9.1 µg/L	15 µg/L	0.5 X GWQS	Increasing Trend allows for modified approach on Flow Chart. Per UAC 317-6, Class III water is allowed to be calculated by 0.5 X the GWQS.	15 µg/L 0.5 X GWQS

Conclusions:

Based on DWMRC review of the background statistics and confirmation that the proposed parameters for GWCL modifications are showing increasing trends not associated with contamination from the mill, it is appropriate to set GWCL's for these parameters at the maximum concentrations per Utah Administrative Code (UAC) R317-6 for Class III groundwater. This review is consistent with the Director approved statistical flowchart which appreciates that a modified approach is appropriate for parameters showing statistically significant increasing trends.

Based on review a letter will be sent to EFR of initial approval of the modified GWCL's on the table above. The letter will include notification that the modifications are subject to public notice and public participation requirements, and that the modifications will not be effective until formal issuance of a modified Permit.

References

[1] Energy Fuels Resources (USA) Inc., August 20, 2017, *Transmittal of Source Assessment Report for Sulfate, Selenium, Total Dissolved Solids, and Uranium in MW-31 White Mesa Mill Groundwater Discharge Permit UGW370004*

[2] Energy Fuels Resources (USA) Inc., August 15, 2017, *White Mesa Uranium Mill Ground Water Monitoring Quality Assurance Plan (QAP), Revision 7.3*

[3] Energy Fuels Resources (USA) Inc., October 12, 2012, *Source Assessment Report*, Prepared by Intera

[4] Energy Fuels Resources (USA) Inc., November 9, 2012, *pH Report*, Prepared by Intera

[5] Hurst, T.G., and Solomon, D.K. University of Utah, 2008, *Summary of Work Completed, data Results, Interpretations and Recommendations for the July 2007 Sampling Event at the Denison Mines, USA White Mesa Uranium Mill Near Blanding,* Utah, Prepared by Department of Geology and Geophysics

[6] Hydro Geo Chem, December 7, 2012, *Pyrite Investigation Report*

[7] Intera, 2007, *Groundwater Data Preparation and Statistical Process Flow for Calculating Groundwater Protection Standards, White Mesa Mill Site, San Juan County, Utah*

[8] Utah Department of Environmental Quality, August 24, 2012, *Utah Division of Radiation Control, Ground Water Discharge Permit, Permit No. UGW370004, Energy Fuels Resources (USA) Inc.*